(12) UK Patent Application (19) GB (11) 2 303 732 (13) A

(43) Date of A Publication 26.02.1997

(21) Application No 9608538.6

(22) Date of Filing 25.04.1996

(30) Priority Data
(31) 95021904 (32) 24.07.1995 (33) KR

(71) Applicant(s)
Samsung Electronics Co Limited

(Incorporated in the Republic of Korea)

416 Maetan-dong, Paldal-gu, Suwon-City, Kyungki-do, Republic of Korea

(72) Inventor(s)
Jung-Ho Lee
Jeom-Geun Kim

(74) Agent and/or Address for Service
Dibb Lupton Broomhead
117 The Headrow, LEEDS, LS1 5JX, United Kingdom

(51) INT CL^6
G11B 5/55

(52) UK CL (Edition O)
G5R RB344 RB36Y RB694 RB782 RB784 RKF
G3N NGE3AA N372 N374 N391A N404
G3R RA25 RA26 RBC26 RBN22 RB246
U1S S2108

(56) Documents Cited
EP 0456371 A2

(58) Field of Search
UK CL (Edition O) G3N NGE3AA, G3R RBN22, G5R RKA RKB RKC RKF RKH
INT CL^6 G11B 5/55 5/596
Online: WPI,JAPIO, INSPEC

(54) **Magnetic disk driving apparatus having a head velocity/position estimator**

(57) A magnetic disk driving apparatus includes a magnetic head and a velocity control signal generator for providing a signal dependent upon the difference between a velocity command value and a current estimated head velocity. Head movement is controlled in accordance with the velocity control signal. The velocity command value is dependent upon the difference between a current estimated head position and a target head position. A position gain factor ($L1\text{-}v_{cmd}$), used in calculating the current estimated head position (θ_c), is obtained by subtracting the velocity command value from a predetermined value and is therefore adjusted according to head velocity, for optimal accuracy in position estimation. A corresponding system for velocity estimation is also disclosed. Both estimations are represented by equation 12 on page 14 of the specification.

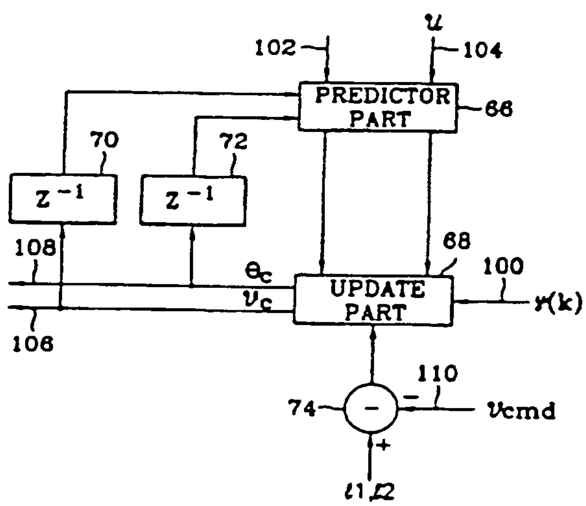
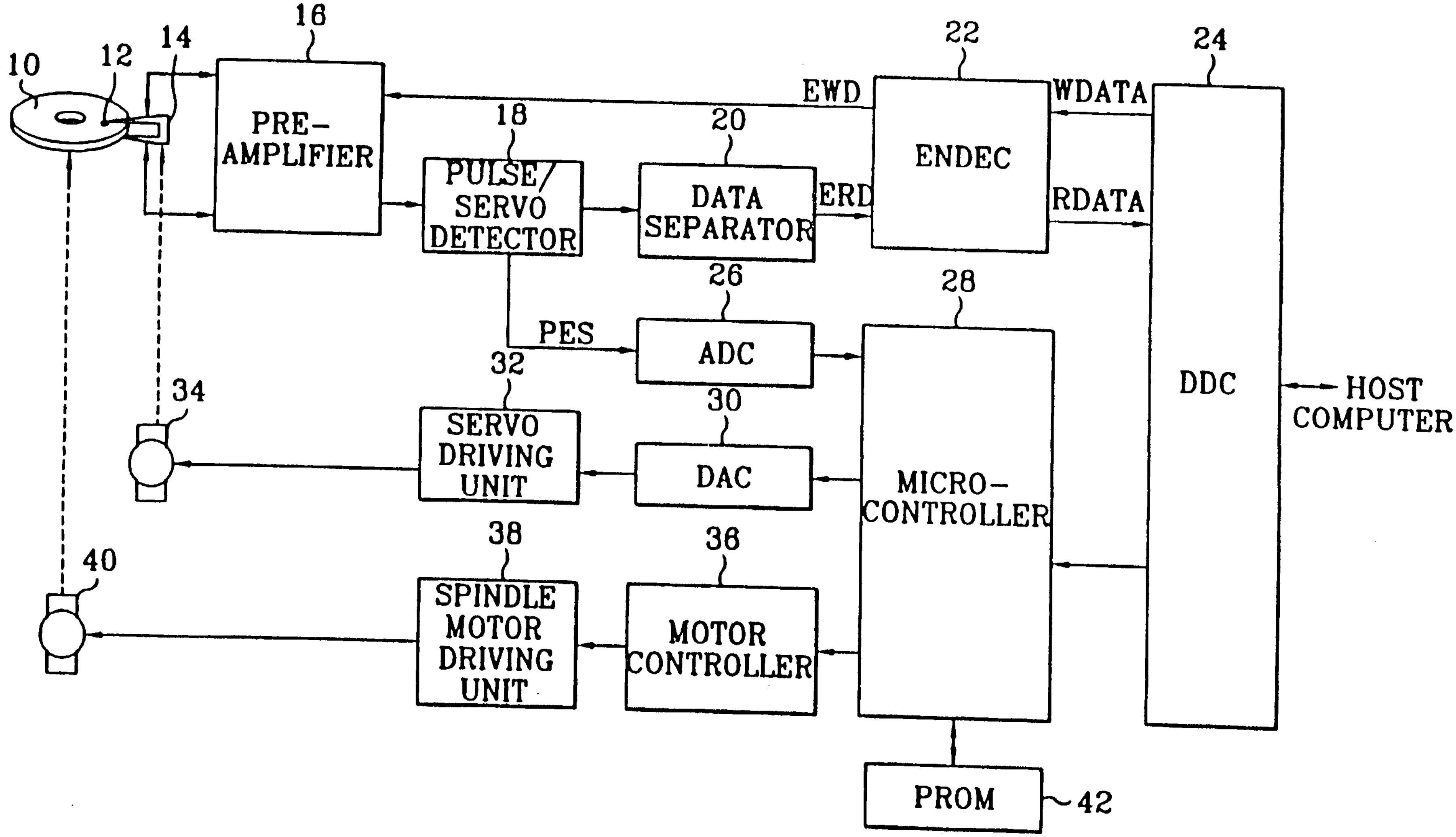
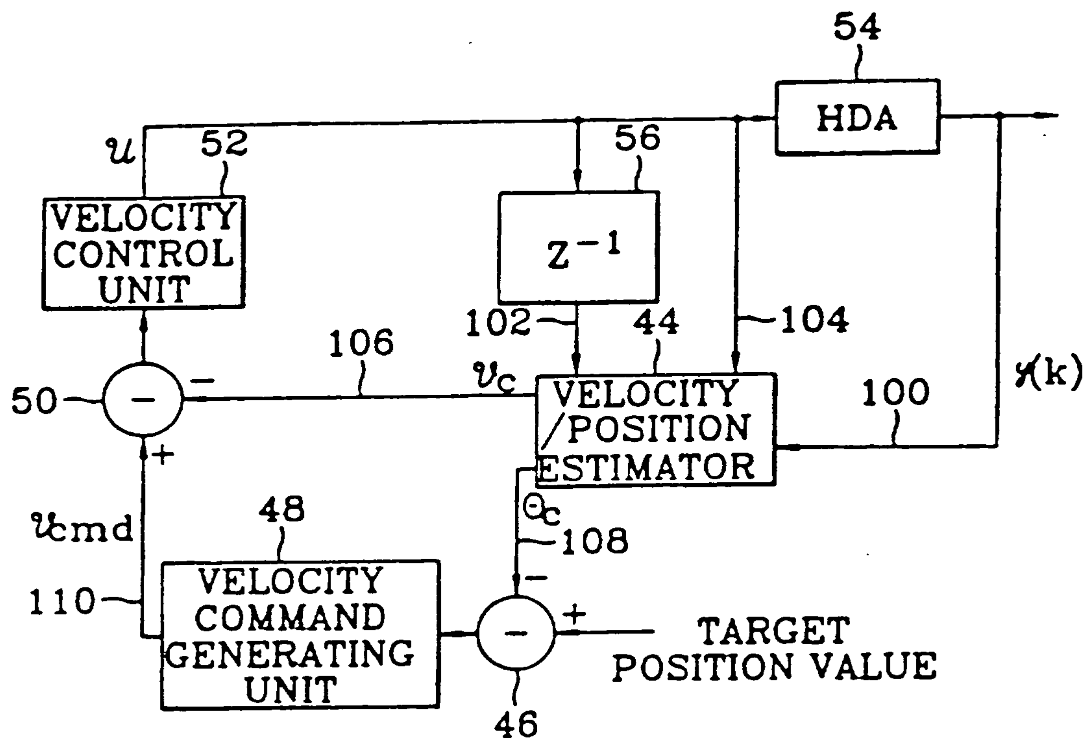


Fig. 4

GB 2 303 732 A

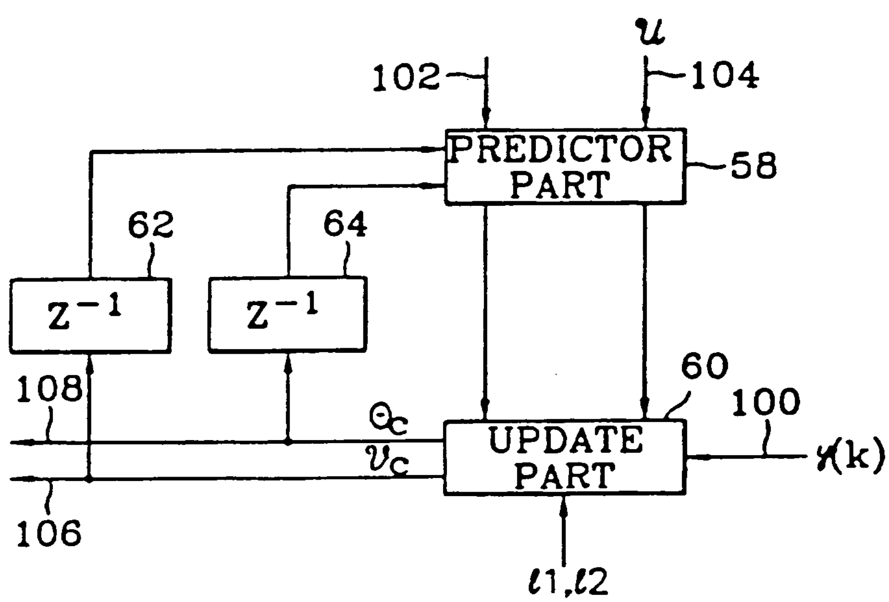


(PRIOR ART)
Fig. 1



(PRIOR ART)

Fig. 2



(PRIOR ART)

Fig. 3

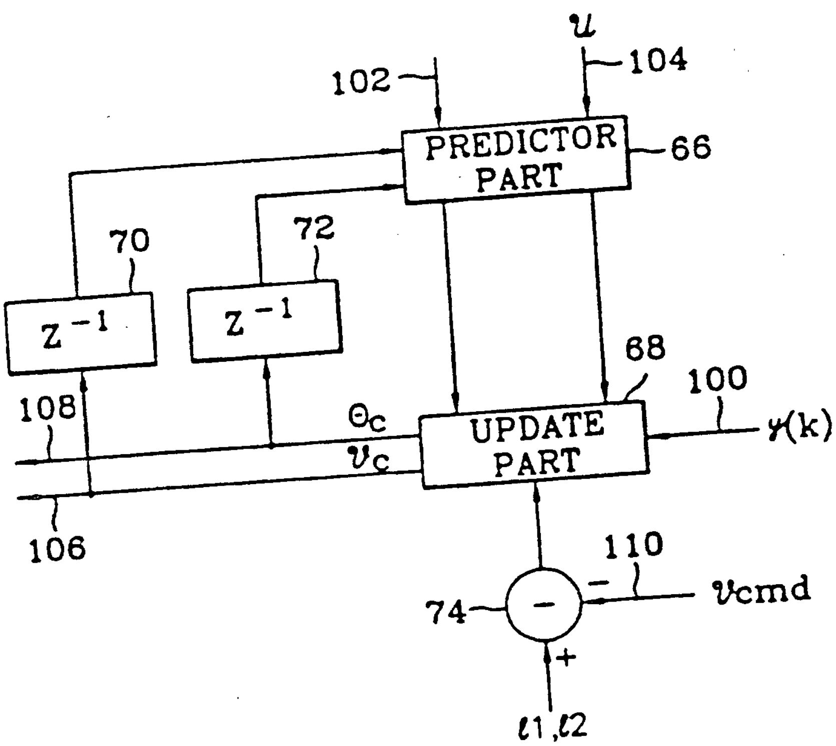

u
102
104
PREDICTOR PART
66
70
72
Z -1
Z -1
68
100
108
Θc
UPDATE PART
y(k)
vc
106
110
74
vcmd
l1,l2

Fig. 4

MAGNETIC DISK DRIVING APPARATUS HAVING A HEAD VELOCITY/POSITION ESTIMATOR

The present invention relates to a magnetic disk driving apparatus having a magnetic head velocity/position estimator used during a track seek operation.

A magnetic disk driving apparatus for magnetically writing/reading data on a rotary magnetic disk can access a large amount of data at a high velocity, and thus, it is widely used as an auxiliary memory of a computer system. In the magnetic disk driving apparatus, data is stored in tracks which extend radially along the magnetic disk surface. These tracks are accessed by a magnetic head for reading, writing and erasing data on the magnetic disk.

The magnetic head is moved in a radial direction along the magnetic disk surface under the control of a head position servo mechanism capable of positioning the magnetic head on any selected track. In order to position the magnetic head at a specific track, the current track position of the magnetic head should be monitored. As stated above, servo information indicative of the track position of the magnetic head is provided by a specific servo pattern which is read from the magnetic disk surface by means of the magnetic head. The servo pattern is permanently written on the magnetic disk surface after assembly of the magnetic disk driving apparatus. When the data on the magnetic disk surface is accessed, the servo pattern is detected by the magnetic head and used as track position information.

An embedded servo method is an example of a method that provides the servo position information. In the embedded servo system, the servo information is arranged between data intervals on the magnetic disk surface. Each portion of servo information includes track position information, a track address, and index information, etc.

The magnetic head is positioned on a specific track using the servo information through two steps known as track seek and track following. The track seek step is performed by moving the magnetic head from the current track to the desired track, that is, by finding the track address of the desired track and moving the magnetic head. The track following step is performed by precisely following the specific track. Thus, when the magnetic head is positioned on a given tracks, the track following step enables the magnetic head to follow a central line of the specific track, and thus accurately perform a read/write operation.

For example, in a conventional magnetic disk driving apparatus utilizing the embedded servo method, two bursts of servo information per track are written beforehand, one on each side of the central line of the track on the magnetic disk surface. As a result, the amount of deviation and a deviation status representative of the magnetic head's position relative to the centre of the track can be determined from the difference between the two servo information signal strengths.

A signal indicative of the amount of deviation and deviation status of the magnetic head is typically referred to as "a position error signal" (PES). The magnetic disk driving apparatus controls the magnetic head so that it is capable of following the centre of the track by utilizing the PES which has values corresponding to deviations in the position of the magnetic head with respect to the centre of the track.

FIG. 1 is a block diagram showing the construction of a general magnetic disk driving apparatus, which can be used for understanding the present invention. FIG. 1 includes a disk and two heads corresponding to both surfaces of the disk. In FIG. 1, a magnetic disk 10 is rotated by a spindle motor 40. A magnetic head 12 is positioned on a surface of the magnetic disk 10 and installed at one end of an arm 14 of a rotary voice coil actuator 34. During data read

operations, a pre-amplifier 16 pre-amplifies a signal read by the magnetic head 12, and during data write operations, it enables the writing of encoded write data (EWD) onto the surface of the magnetic disk 10 through the magnetic head 12. The EWD is generated and provided by an encoder/decoder 22 (ENDEC).

A pulse/servo detector 18 detects an amplified peak value of the signal pre-amplified in the preamplifier 16, and generates a data pulse. Thus, the pulse/servo detector 18 detects the amplitude of two bursts and then generates a signal indicative of the difference between the amplitude levels; that is, the pulse/servo detector 18 generates the PES. The data pulse generated from the pulse/servo detector 18 is provided to a data separator 20 and the PES is provided to an analog-to digital converter 26 (hereinafter, referred to as ADC). The ADC 26 converts the PES into a digital step value corresponding to its level, and provides the converted value to a micro-controller 28. The data separator 20 separates encoded read data (ERD) which is synchronized with a constant clock from the data pulse generated by the pulse/servo detector 18, and then applies the separated data ERD to the ENDEC 22.

The ENDEC 22 decodes the ERD received from the data separator 20 and provides the result as read data (RDATA) to a disk data controller 24 (DDC). Alternatively, the ENDEC 22 also encodes written data (WDATA) provided from the DDC 24 and then applies the encoded data EWD to the pre-amplifier 16. The DDC 24 is controlled by the micro-controller 28 and writes the data received from a host computer onto the surface of the magnetic disk 10 via the ENDEC 22 and the pre-amplifier 16. Alternatively, the DDC 24 also reads data from the magnetic disk 10 and sends the read data received via the ENDEC 22 to the host computer. Furthermore, the DDC 24 acts as an interface for communication between the host computer and the micro-controller 28.

The micro-controller 28 controls the DDC 24 and controls the track seeking and track following operations, in response to a read/write command received from the host computer. The micro-controller 28 controls the track following operation by using the PES value applied from the ADC 26. The digital-to-analog converter (DAC) 30 converts a control value generated by the micro-controller 28 to control the position of the magnetic head 12 into an analog signal. A servo driving unit 32 generates an electric current for driving the actuator 34 according to a signal applied from the DAC 30 and applies the electric current to the voice coil of the actuator 34. The actuator 34 moves the magnetic head 12 along the surface of the magnetic disk 10 in correspondence with the direction or the level of the electric current applied from the servo driving unit 32.

A motor controller 36 controls a spindle motor driving unit 38 in accordance with a control value generated by the micro-controller 28 to control the rotation of the magnetic disk 10. The spindle motor driving unit 38 drives the spindle motor 40 in accordance with the control of the motor controller 36 to rotate the magnetic disk 10. A programmable read only memory 42 (PROM) stores a variety of data for performing the servo control operation of the micro-controller 28.

FIG. 2 is a block diagram showing a general track seek control algorithm, which has hitherto been used for controlling the track seeking operation in the magnetic disk driving apparatus described above. In FIG. 2, a head disk assembly 54 (HDA) comprises the magnetic disk 10, the magnetic head 12, the arm 14 of the actuator 34, the pre-amplifier 16, the DAC 30, the servo driving unit 32, and the actuator 34 in FIG. 1. Furthermore, a velocity command generating unit 48 is included with a look-up table in the PROM 42. The remainder of the functional blocks FIG. 2, eg. the velocity/position estimator 44, the first and second subtracting units 46 and 50, the velocity control unit 52, and the delay unit 56, are constituted by the

micro-controller 28 and implemented in software.

The velocity/position estimator 44 estimates a current velocity/position of the magnetic head 12 from a current head position measured value $y(k)$ applied from the HDA 54, a current velocity control value u generated by the velocity control unit 52 and a value applied from the first delay unit 56, to generate a current head velocity estimated value υ_c and a current head position estimated value θ_c. The current head position measured value $y(k)$ is a track address and the PES read by the magnetic head 12 of the HDA 54. Generally, the track address is a grey code written on the surface of the magnetic disk 10 and, upon being read on the surface of the magnetic head 10, is decoded and provided to the micro-controller 28.

The first subtracting unit 46 subtracts the current head position estimated value θ_c from a target position value, and applies the difference between the values, i.e. a position error value, to the velocity command generating unit 48. The velocity command generating unit 48 generates a velocity command value υ_{cmd} corresponding to the position error value among a plurality of velocity command values stored in the look-up table. Likewise, the second subtracting unit 50 subtracts the current head velocity estimated value υ_c from the velocity command value υ_{cmd}, and thus applies the difference between the above values, i.e., a velocity error value to the velocity control unit 52. The velocity control unit 52 generates the current velocity control value u in accordance with the velocity error value and provides the generated value to the DAC 30 of the HDA 54. The first delay unit 56 delays the current velocity control value u by 1 cycle or sample and provides the delayed value to the velocity/position estimator 44.

Since position information obtained by the PES is the only information measurable in the HDA plant during the track

seeking operation, problems arise in that, when the velocity information required for controlling the velocity in the track seeking operation is obtained by differentiating the position information, the velocity information obtained is sensitive to external noise, thus deteriorating the precision of the velocity information. Accordingly, during control of the track seek operation of most hard disk drives (HDD), the velocity/position information is obtained from an estimator using a theoretical model.

Now, referring to the construction of the velocity/position estimator **44**, the dynamics of the HDA 54 can be represented by the following expressions (1) and (2).

$$x(k+1)=Ax(k)+Bu(k)\ldots\ldots(1)$$

$$y(k)=Cx(k)\ldots\ldots(2)$$

From the above expressions (1) and (2), A, B, and C, respectively, can be expressed as follows in expressions (3), (4) and (5).

$$A=\begin{bmatrix}1 & 1 & kd\\ 0 & 1 & 2kd\\ 0 & 0 & 1\end{bmatrix}\ldots\ldots(3)$$

$$B=\begin{bmatrix}kd\\ 2kd\\ 0\end{bmatrix}\ldots\ldots(4)$$

$$c=[1\ \ 0\ \ 0]\ldots\ldots(5)$$

Also, x(k) can be expressed as shown by the following expression (6).

$$x(k)=\begin{bmatrix}\theta(k)\\ \upsilon(k)\\ \omega(k)\end{bmatrix}\ldots\ldots(6)$$

In the above expression (6), $\theta(k)$ represents position, $\upsilon(k)$ represents velocity and $\omega(k)$ represents a bias.

Meanwhile, FIG. 3 is a block diagram showing the algorithm of a general velocity/position estimator, in which the velocity/position estimator 44 comprises a predictor part 58 and an update part 60. In FIG. 3, signal lines 100, 102, 104, 106, and 108 are same as those of FIG. 2. The predictor part 58 receives the outputs of second and third delay units 62 and 64 and the outputs of the velocity control unit 52 and the first delay unit 56, thus to obtain a predicted state value $x_p(k)$ and a predicted output value $y_p(k)$, respectively, as shown by the following expressions (7) and (8).

$$x_p(k)=Ax(k-1)+Bu(k-1)\ldots\ldots(7)$$

$$y_p(k)=Cx_p(k)\ldots\ldots(8)$$

The update part 60 generates the current head position measured value $y(k)$ applied from the HDA 54, the current head velocity estimated value υ_p applied from the predictor part 58, and the current head velocity estimated value υ_c and the current head position estimated value θ_c from the current head position predicted value θ_p. The update state value $x_c(k)$ of the update part 60 can be represented as shown by the following expression (9).

$$x_c(k)=x_p(k)+(-L)[y(k)-y_p(k)]\ldots\ldots(9)$$

Since a delay time exists in a digital realisation, the bias value $\omega(k)$ of the estimated values is removed to leave the following expressions (10) and (11) for each of the

predictor part 58 and the update part 60.

$$\begin{bmatrix}\theta_p\\ \upsilon_p\end{bmatrix}=\begin{bmatrix}1 & 1\\ 0 & 1\end{bmatrix}\begin{bmatrix}\theta_c\\ \upsilon_c\end{bmatrix}+\begin{bmatrix}2kd2-kd1\\ 2kd2\end{bmatrix}[u(k-1)+\hat{\omega}]$$

$$+\begin{bmatrix}kd+kd1-2kd2\\ 2kd-2kd2\end{bmatrix}[u(k)+\hat{\omega}]\ \ldots\ldots(10)$$

$$\begin{bmatrix}\theta_c\\ \upsilon_c\end{bmatrix}=\begin{bmatrix}\theta_p\\ \upsilon_p\end{bmatrix}+\begin{bmatrix}L1\\ L2\end{bmatrix}[y(k)-\theta_p(k)]\ \ldots\ldots(11)$$

In the above expression (11), θ_c represents the current head position estimated value, υ_c represents the current head velocity estimated value, θ_p represents the current head position predicted value, and υ_p represents the current head velocity predicted value. L1 represents the head position estimated gain value, L2 represents the head velocity estimated gain value, y(k) represents the current head position measured value, and $\theta_p(k)$ represents the current head position predicted value. Hence, $[y(k)-\theta_p(k)]$ indicates the current estimated error value.

However, when the velocity of the magnetic head becomes high, the current head position measured value y(k) is noisy. Eventually, the problem arises that the noise can be amplified and the current head position estimated value θ_c and the current head velocity estimated value υ_c can be in error.

It is therefore an object of the present invention to provide a velocity/position estimator of a magnetic head, which overcomes this problem. The present invention seeks to do this by adjusting the gain in accordance with the moving velocity of the magnetic head.

Accordingly, a first aspect of the present invention

provides a magnetic disk driving apparatus which includes:

a magnetic head;

a velocity control signal generator adapted to generate a velocity control signal dependent upon the difference between a velocity command value and a current estimated head velocity; and

means for controlling the head in accordance with the velocity control signal, in which:

the velocity command value is dependent upon the difference between a current estimated head position and a target head position;

the current estimated head position is dependent upon the difference between a current predicted head position, calculated according to a predetermined algorithm, and a current error value modified by a position gain factor;

the current error value is dependent upon the difference between the predicted head position and a measured position of the head; and

the position gain factor decreases as the velocity command value increases.

Preferably, the apparatus comprises:

a velocity command signal generator adapted to generate a velocity command signal υ_{cmd} representative of the velocity command value;

a velocity estimator adapted to generate a current estimated head velocity signal representative of the current estimated head velocity; and in which:

the velocity control signal generator comprises a subtracter which receives at its input terminals the velocity command signal and the current estimated head velocity.

The velocity control signal generator preferably further comprises a velocity control unit for generating the velocity control signal from the output of the subtracter.

The apparatus preferably includes:

a position estimator adapted to generate a current estimated head position signal representative of the current estimated head position;

a velocity command signal generator adapted to generate a velocity command signal representative of the velocity command value and comprising a subtracter which receives at its input terminals the current estimated head position signal and a signal representative of the target head position.

The velocity signal generator preferably further comprises a velocity command generating unit adapted to generate the velocity command signal in dependence upon the output of the subtracter.

The velocity command generating unit may include a look-up table.

Preferably, the current estimated position is substantially equal to the difference between the current predicted head position and the current error value multiplied by the position gain factor.

Thus, the apparatus may comprise:

a position predictor adapted to generate a current predicted head position signal representative of the current predicted head position;

a position gain signal generator adapted to generate a position gain signal representative of the said position gain factor;

a position updater adapted to receive the current predicted head position signal, a signal representative of the measured position of the head and the position gain signal and adapted to generate a current estimated head position signal representative of the current estimated head position.

Preferably, the position gain factor is substantially equal to a predetermined value minus the velocity command value.

Thus, the apparatus may include:

a velocity command signal generator adapted to generate a velocity command signal representative of the velocity command value; and

a position gain signal generator which comprises a subtracter which receives at its input terminals a signal representative of the predetermined value and the velocity command signal.

Preferably, the current error value is substantially equal to the difference between the predicted head position and the measured position of the head.

The current predicted head position may be calculated from a delayed estimated head position, a delayed estimated head velocity, the velocity control signal and a delayed velocity control signal.

A second aspect of the present invention provides a magnetic disk driving apparatus which includes:

a magnetic head;

a velocity control signal generator adapted to generate a velocity control signal dependent upon the difference between a velocity command value and a current estimated head velocity; and

means for controlling the head in accordance with the velocity control signal, in which:

the velocity command value is dependent upon the difference between a current estimated head position and a target head position;

the current estimated head velocity is dependent upon the difference between a current predicted head velocity, calculated according to a predetermined algorithm, and a current error value modified by a velocity gain factor;

the current error value is dependent upon the difference between the predicted head position and a measured position of the head; and

the velocity gain factor decreases as the velocity command value increases.

In addition, in the apparatus according to the first aspect of the invention, the current estimated head velocity may be dependent upon the difference between a current predicted head velocity, calculated according to a predetermined algorithm, and the current error value modified by a velocity gain factor, in which the velocity gain factor decreases as the velocity command value increases.

Preferably, the current estimated velocity is substantially equal to the difference between the current predicted head velocity and the current error value multiplied by the velocity gain factor.

Thus, the apparatus may comprise:

a position predictor adapted to generate a current predicted head position signal representative of the current predicted head position;

a velocity predictor adapted to generate a current predicted head velocity signal representative of the current predicted head velocity;

a velocity gain signal generator adapted to generate a velocity gain signal representative of the said velocity gain factor;

a velocity updater adapted to receive the current predicted head velocity signal, the current predicted head position signal, a signal representative of the measured position of the head and the velocity gain signal and adapted to generate a current estimated head position signal representative of the current estimated head position.

The velocity gain factor is preferably substantially equal to a second predetermined value minus the velocity command value.

Thus, the apparatus may include:

a velocity command signal generator adapted to generate a velocity command signal representative of the

velocity command value; and

a velocity gain signal generator which comprises a subtracter which receives at its input terminals a signal representative of the second predetermined value and the velocity command signal.

The current predicted head velocity may be calculated from a delayed estimated head position, a delayed estimated head velocity, the velocity control signal and a delayed velocity control signal.

Conveniently, the signal generators, the estimators, the control units, the predictors, the updaters and/or the subtracters may be constituted by a CPU and implemented in software.

A more complete appreciation of this invention, and many of the attendant advantages thereof, will be readily apparent as the same becomes better understood by reference to the following detailed description of a preferred embodiment when considered in conjunction with the accompanying drawings, in which like reference symbols indicate the same or similar elements components and in which:

FIG. 1 is a block diagram showing the construction of a general magnetic disk driving apparatus;

FIG. 2 is a block diagram showing a general track seek control algorithm;

FIG. 3 is a block diagram showing the algorithm of a general velocity/position estimator; and

FIG. 4 is a block diagram showing the algorithm of a state estimator according to the present invention.

In that which follows, detailed descriptions of known functions and constructions which would otherwise unnecessarily obscure the subject-matter of the present invention will be avoided.

FIG. 4 is a block diagram showing the algorithm of a state estimator according to the present invention. In FIG, 4,

the signal lines 100, 102, 104, 106, and 108 are the same as those of FIG. 2. A predictor part 66 receives the outputs of second and third delay units 70 and 72 which delaying by 1 cycle or sample the current estimated head velocity value υ_c and the current estimated head position value θ_c and the outputs of the velocity control unit 52 and the first delay unit 56, generates a current predicted head velocity value υ_p and a current predicted head position value θ_p and applies the results to an update part 68, as illustrated by in expression (10). A subtracting unit 74 subtracts the velocity command value υ_{cmd} of the velocity command generating unit 48 from gain values L1 and L2 and applies the result to the update part 68. Thus, the update part 68 generates the current estimated head velocity value υ_c and the current estimated head position value θ_c as shown by the following expression (12), from a current head position measured value $y(k)$ applied from a HDA 54, the current head velocity predicted value υ_p and the current head position predicted value θ_p applied from the predictor part 66, and the output of the subtracting unit 74.

$$\begin{bmatrix}\theta_c\\ \upsilon_c\end{bmatrix} = \begin{bmatrix}\theta_p\\ \upsilon_p\end{bmatrix} + \begin{bmatrix}L1-\upsilon_{cmd}\\ L2-\upsilon_{cmd}\end{bmatrix} [y(k)-\theta_p(k)] \ldots\ldots (12)$$

In the velocity/position estimator as described above, the gain is automatically adjusted in accordance with the moving velocity of the magnetic head. That is, when the moving velocity of the magnetic head is high, the estimated error has a high possibility of being contained in the track position information or burst values obtained through the magnetic head. Thus, the gain thereof may be decreased, thus increasing the strength of the estimated error. However, when the precision of the estimated value is high due to the decreased moving velocity of the magnetic head, the gain may be increased, thus increasing the estimating capacity.

As an example, now that the velocity command value υ_{cmd} becomes high when the moving velocity of the magnetic head is high, the gain values applied and adjusted from the subtracting unit 74 to the update part 68, namely, $L1-\upsilon_{cmd}$ and $L2-\upsilon_{cmd}$ in the above expression (12) become low. On the other hand, now that the velocity command value υ_{cmd} becomes small when the moving velocity of the magnetic head is low, the gain values applied and adjusted from the subtracting unit 74 to the update part 68, namely, $L1-\upsilon_{cmd}$ and $L2-\upsilon_{cmd}$ in the above expression (12) become high. Consequently, according to the present invention as mentioned previously, the gain of the velocity/position estimator can be automatically maintained at an optimum in accordance with the moving velocity of the magnetic head.

While the foregoing description has illustrated the adjustment of the current head position/velocity estimated gain values L1 and L2 in accordance with the velocity command value υ_{cmd}, the adjusted gain may be applied to just one of the head velocity and head position as the need arises.

While there have been illustrated and described what are considered to be preferred embodiments of the present invention, it will be understood by those skilled in the art that various changes and modifications and equivalents may be substituted for elements thereof without departing from the scope of the present invention. Therefore, it is intended that the present invention not be limited to the particular embodiments disclosed as the best mode contemplated for carrying out the present invention, but that the present invention includes all embodiments falling within the scope of the appended claims.

CLAIMS

1. A magnetic disk driving apparatus which includes:

a magnetic head;

a velocity control signal generator adapted to generate a velocity control signal dependent upon the difference between a velocity command value and a current estimated head velocity; and

means for controlling the head in accordance with the velocity control signal, in which:

the velocity command value is dependent upon the difference between a current estimated head position and a target head position;

the current estimated head position is dependent upon the difference between a current predicted head position, calculated according to a predetermined algorithm, and a current error value modified by a position gain factor;

the current error value is dependent upon the difference between the predicted head position and a measured position of the head; and

the position gain factor decreases as the velocity command value increases.

2. Apparatus according to claim 1 comprising:

a velocity command signal generator adapted to generate a velocity command signal υ_{cmd} representative of the velocity command value;

a velocity estimator adapted to generate a current estimated head velocity signal representative of the current estimated head velocity; and in which:

the velocity control signal generator comprises a subtracter which receives at its input terminals the velocity command signal and the current estimated head velocity.

3. Apparatus according to claim 2 in which the velocity control signal generator further comprises a velocity control unit for generating the velocity control signal

from the output of the subtracter.

4. Apparatus according to any one of claims 1-3 including:

a position estimator adapted to generate a current estimated head position signal representative of the current estimated head position;

a velocity command signal generator adapted to generate a velocity command signal representative of the velocity command value and comprising a subtracter which receives at its input terminals the current estimated head position signal and a signal representative of the target head position.

5. Apparatus according to claim 4, in which the velocity signal generator further comprises a velocity command generating unit adapted to generate the velocity command signal in dependence upon the output of the subtracter.

6. Apparatus according to claim 5 in which the velocity command generating unit includes a look-up table.

7. Apparatus according to any preceding claim in which the current estimated position is substantially equal to the difference between the current predicted head position and the current error value multiplied by the position gain factor.

8. Apparatus according to claim 7 comprising:

a position predictor adapted to generate a current predicted head position signal representative of the current predicted head position;

a position gain signal generator adapted to generate a position gain signal representative of the said position gain factor;

a position updater adapted to receive the current predicted head position signal, a signal representative of the measured position of the head and the position gain signal and adapted to generate a current estimated head

position signal representative of the current estimated head position.

9. Apparatus according to any preceding claim in which the position gain factor is substantially equal to a predetermined value minus the velocity command value.

10. Apparatus according to claim 9 including:

a velocity command signal generator adapted to generate a velocity command signal representative of the velocity command value; and

a position gain signal generator which comprises a subtracter which receives at its input terminals a signal representative of the predetermined value and the velocity command signal.

11. Apparatus according to any preceding claim in which the current error value is substantially equal to the difference between the predicted head position and the measured position of the head.

12. Apparatus according to any preceding claim in which the current predicted head position is calculated from a delayed estimated head position, a delayed estimated head velocity, the velocity control signal and a delayed velocity control signal.

13. A magnetic disk driving apparatus which includes:

a magnetic head;

a velocity control signal generator adapted to generate a velocity control signal dependent upon the difference between a velocity command value and a current estimated head velocity; and

means for controlling the head in accordance with the velocity control signal, in which:

the velocity command value is dependent upon the difference between a current estimated head position and a target head position;

the current estimated head velocity is dependent upon

the difference between a current predicted head velocity, calculated according to a predetermined algorithm, and a current error value modified by a velocity gain factor;

the current error value is dependent upon the difference between the predicted head position and a measured position of the head; and

the velocity gain factor decreases as the velocity command value increases.

14. Apparatus according to any one of claims 1-12 in which the current estimated head velocity is dependent upon the difference between a current predicted head velocity, calculated according to a predetermined algorithm, and the current error value modified by a velocity gain factor, in which the velocity gain factor decreases as the velocity command value increases.

15. Apparatus according to claim 13 or claim 14 in which the current estimated velocity is substantially equal to the difference between the current predicted head velocity and the current error value multiplied by the velocity gain factor.

16. Apparatus according to claim 15 comprising:

a position predictor adapted to generate a current predicted head position signal representative of the current predicted head position;

a velocity predictor adapted to generate a current predicted head velocity signal representative of the current predicted head velocity;

a velocity gain signal generator adapted to generate a velocity gain signal representative of the said velocity gain factor;

a velocity updater adapted to receive the current predicted head velocity signal, the current predicted head position signal, a signal representative of the measured position of the head and the velocity gain signal and adapted to generate a current estimated head position signal representative of the current estimated head

position.

17. Apparatus according to any one of claims 13-16 in which the velocity gain factor is substantially equal to a second predetermined value minus the velocity command value.

18. Apparatus according to claim 17 including:

a velocity command signal generator adapted to generate a velocity command signal representative of the velocity command value; and

a velocity gain signal generator which comprises a subtracter which receives at its input terminals a signal representative of the second predetermined value and the velocity command signal.

19. Apparatus according to any one of claims 13-16 in which the current predicted head velocity is calculated from a delayed estimated head position, a delayed estimated head velocity, the velocity control signal and a delayed velocity control signal.

20. Apparatus according to any preceding claim in which one or more of the signal generators, the estimators, the control units, the predictors, the updaters and/or the subtracters are constituted by a CPU and implemented in software.

21. A magnetic disk driving apparatus according to claim 1 or claim 13 and substantially as described herein with reference to Fig. 4 of the accompanying drawings.

The Patent Office

21

Application No:	GB 9608538.6	**Examiner:**	Donal Grace
Claims searched:	1 to 21	**Date of search:**	18 July 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G3N (NGE3AA) G3R (RBN22) G5R (RKA, RKB, RKC, RKF, RKH)

Int Cl (Ed.6): G11B 5/55, 5/596

Other: Online: WPI, JAPIO, INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	EP 0456371 A2 (SEAGATE) see line 10, column 13 to line 16, column 14	1, 13

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.